

IN THE CLAIMS

Please amend the claims as follows, substituting any amended claim(s) for the corresponding pending claim(s):

1. 1. (Original) A radio frequency integrated circuit (RFIC) comprises:
  2. transmitter section operably coupled to convert outbound baseband signals into outbound radio frequency (RF) signals;
  4. receiver section operably coupled to convert inbound RF signals into inbound baseband signals, wherein the receiver section includes: a low noise amplifier operably coupled to amplify the inbound RF signals to produce amplified inbound RF signals;
  7. down-conversion module operably coupled to convert the amplified inbound RF signals into baseband in-phase components and quadrature components;
  9. orthogonal-normalizing module operably coupled to:
    10. obtain a first coefficient that is based on at least one of power of the baseband in-phase components, power of the baseband quadrature components, and cross-correlation between the baseband in-phase components and the baseband quadrature components;
    13. obtain a second coefficient that is based on at least one of the power of the baseband in-phase components, the power of the baseband quadrature components, and the cross-correlation between the baseband in-phase components and the baseband quadrature components;
    16. normalize an orthogonal relationship between the baseband in-phase components and the baseband quadrature components based on the first coefficient and the second coefficient to produce normalized in-phase components and normalized quadrature components; and
    19. baseband processor operably coupled to recapture data from the normalized in-phase and quadrature components.
1. 2. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module comprises:
  2. a first multiplier module operably coupled to multiple the baseband in-phase components with the first coefficient to produce the normalized in-phase components;
  4. a second multiplier module operably coupled to multiple the baseband in-phase components with the second coefficient to produce the cross-correlation; and
  6. a subtraction module operably coupled to subtract the cross-correlation from the baseband quadrature components to produce the normalized quadrature components.

1    3. (Original) The RFIC of claim 2, wherein the first multiplier module comprises:  
2         a first plurality of shift registers operably coupled to produce a plurality of shifted representations  
3         of the baseband in-phase components;  
4         a switch matrix operably coupled to pass selected ones of the plurality of shifted representations of  
5         the baseband in-phase components and the baseband in-phase components based on the first coefficient;  
6         and  
7         an adder operably coupled to add the selected ones of the plurality of shifted representations of  
8         the baseband in-phase components and the baseband in-phase components to produce the normalized in-  
9         phase components.

1    4. (Original) The RFIC of claim 2, wherein the second multiplier module comprises:  
2         a first plurality of shift registers operably coupled to produce a plurality of shifted representations  
3         of the baseband in-phase components;  
4         a switch matrix operably coupled to pass selected ones of the plurality of shifted representations of  
5         the baseband in-phase components based on the second coefficient; and  
6         an adder operably coupled to add the selected ones of the plurality of shifted representations of  
7         the baseband in-phase components to produce the cross-correlation.

1    5. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module comprises:  
2         a first multiplier module operably coupled to multiply the baseband in-phase components with the  
3         second coefficient to produce the cross-correlation;  
4         a subtraction module operably coupled to subtract the cross-correlation from the baseband  
5         quadrature components to produce phase adjusted quadrature components; and  
6         a second multiplier module operably coupled to multiply the phase adjusted quadrature  
7         components with the first coefficient to produce the normalized quadrature components, wherein the  
8         baseband in-phase components are passed as the normalized in-phase components.

1    6. (Currently Amended) The RFIC of claim 1, wherein the orthogonal-normalizing module  
2         comprises:  
3         a first programmable register for storing the first coefficient; and  
4         a second programmable register for storing the second coefficient, wherein the first and second  
5         coefficients are determined by a ~~trial and error manufacturing test~~ trial and error manufacturing test.

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1        7. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module comprises:  
2              a full matrix multiply module operably coupled to multiply the baseband in-phase components  
3              and the baseband quadrature components with a coefficient matrix that includes the first and second  
4              coefficients to produce the normalized in-phase components and the normalized quadrature components.

1        8. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module further functions to:  
2              measure local oscillation leakage power to produce a first power measurement;  
3              provide a first magnitude signal to an in-phase portion of the receiver section and a zero  
4              magnitude signal to a quadrature portion of the receiver section;  
5              measure power of the in-phase portion and power of the quadrature portion while processing the  
6              first magnitude signal and the zero magnitude signal, respectively, to produce a second power  
7              measurement;  
8              provide the first magnitude signal to the quadrature portion of the receiver section and the zero  
9              magnitude signal to the in-phase portion of the receiver section;  
10             measure the power of the in-phase portion and the power of the quadrature portion while  
11             processing the zero magnitude signal and the first magnitude signal, respectively, to produce a third  
12             power measurement;  
13             determine a gain imbalance based on the first, second, and third power measurements;  
14             provide a second magnitude signal to the in-phase portion and to the quadrature portion;  
15             measure the power of the in-phase and quadrature portions while processing the second  
16             magnitude signal to produce a fourth power measurement;  
17             provide the second magnitude signal to the in-phase portion and a negative second magnitude  
18             signal to the quadrature portion;  
19             measure the power of the in-phase portion and the power of the quadrature portion while  
20             processing the second magnitude signal and the negative second magnitude signal, respectively, to  
21             produce a fifth power measurement; and  
22             determine a phase imbalance based on the first, fourth, and fifth power measurements, wherein  
23             the gain imbalance and the phase imbalance correspond to the power of the baseband in-phase  
24             components, the power of the baseband quadrature components, and the cross-correlation between the  
25             baseband in-phase components and the baseband quadrature components to determine the first and second  
26             coefficients.

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1 9. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module further functions to  
2 obtain the first and second coefficients by:

3 measuring in-phase signal level of the receiver section while processing a sine wave;

4 measuring quadrature signal level of the receiver section while processing the sine wave;

5 determining the power of the baseband in-phase components based on the in-phase signal level;

6 determining the power of the baseband quadrature components based on the quadrature signal

7 level;

8 determining cross-correlation power based on the in-phase signal level and the quadrature signal

9 level; and

10 determining the first and second coefficients based on the power of the baseband in-phase

11 components, the of the baseband quadrature components, and the cross-correlation power.

1 10. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module normalizes the  
2 orthogonal relationship between the baseband in-phase components and the baseband quadrature  
3 components by:

4 selecting one of the baseband in-phase components and the baseband quadrature components as a  
5 reference component; and

6 normalizing another one of the baseband in-phase components and the baseband quadrature

7 components to the reference component.

1 11. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module further functions to:  
2 update the first and second coefficients to compensate for at least one of temperature variation and aging.

1       12. (Original) A radio frequency integrated circuit (RFIC) comprises:  
2              transmitter section operably coupled to convert outbound baseband signals into outbound radio  
3              frequency (RF) signals;  
4              receiver section operably coupled to convert inbound RF signals into inbound data, wherein the  
5              receiver section includes: a low noise amplifier operably coupled to amplify the inbound RF signals to  
6              produce amplified inbound RF signals;  
7              down-conversion module operably coupled to convert the amplified inbound RF signals into  
8              baseband in-phase components and quadrature components;  
9              orthogonal-normalizing module including:  
10                  an in-phase power module operably coupled to determine power of the baseband in-phase  
11              components;  
12                  a quadrature power module operably coupled to determine power of the quadrature  
13              components;  
14                  a cross-correlation power module operably coupled to determine a cross-correlation  
15              power based on the baseband in-phase and quadrature components; and  
16                  normalizing module operably coupled to normalize the baseband in-phase components  
17              and the baseband quadrature components based on the power of the baseband in-phase  
18              components, the power of the baseband quadrature components, and the cross-correlation power  
19              to produce normalized in-phase components and normalized quadrature components; and  
20              baseband processor operably coupled to recapture the inbound data from the normalized in-phase  
21              and quadrature components.

1       13. (Original) The RFIC of claim 12, wherein the normalizing module comprises:  
2              a coefficient module operably coupled to determine coefficients based on the power of the  
3              baseband in-phase components, the power of the baseband quadrature components, and the cross-  
4              correlation power, wherein the baseband in-phase components and the baseband quadrature components  
5              are normalized based on the coefficients.

1       14. (Original) The RFIC of claim 12, wherein the in-phase power module comprises:  
2              a multiplier operably coupled to square the baseband in-phase components to produce squared in-  
3              phase values; and  
4              an accumulator operably coupled to accumulate the squared in-phase values for a predetermined  
5              period of time to produce the power of the baseband in-phase components.

- 1    15. (Original) The RFIC of claim 12, wherein the quadrature power module comprises:
  - 2        a multiplier operably coupled to square the baseband quadrature components to produce squared
  - 3        quadrature values; and
  - 4        an accumulator operably coupled to accumulate the squared quadrature values for a
  - 5        predetermined period of time to produce the power of the baseband quadrature components.
- 1    16. (Original) The RFIC of claim 12, wherein the cross-correlation power module comprises:
  - 2        a multiplier operably coupled to multiply the baseband in-phase components and the baseband
  - 3        quadrature components to produce cross-correlation values; and
  - 4        an accumulator operably coupled to accumulate the cross-correlation values for a predetermined
  - 5        period of time to produce the cross-correlation power.
- 1    17. (Original) A radio frequency integrated circuit (RFIC) comprises:
  - 2        receiver section operably coupled to convert inbound radio frequency (RF) signals into inbound
  - 3        baseband signals;
  - 4        transmitter section operably coupled to convert outbound data into outbound RF signals, wherein
  - 5        the transmitter section includes:
    - 6            baseband processor operably coupled to convert the outbound data into the baseband in-
    - 7            phase components and baseband quadrature components;
    - 8            orthogonal-normalizing module operably coupled to:
      - 9              obtain a first coefficient that is based on at least one of a gain imbalance and
      - 10             phase imbalance;
      - 11              obtain a second coefficient that is based on at least one of the gain imbalance and
      - 12             the phase imbalance;
      - 13              normalize an orthogonal relationship between the baseband in-phase components
      - 14             and the baseband quadrature components based on the first coefficient and the second
      - 15             coefficient to produce normalized in-phase components and normalized quadrature
      - 16             components;
    - 17            up-conversion module operably coupled to convert the normalized in-phase components and
    - 18            normalized quadrature components into RF signals; and
    - 19            power amplifier operably coupled to amplify the RF signals to produce the outbound RF signals.

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1    18. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module comprises:  
2         a first multiplier module operably coupled to multiple the baseband in-phase components with the  
3         first coefficient to produce the normalized in-phase components;  
4         a second multiplier module operably coupled to multiple the baseband in-phase components with  
5         the second coefficient to produce cross coupled in-phase components; and  
6         a subtraction module operably coupled to subtract the cross coupled in-phase components from  
7         the baseband quadrature components to produce the normalized quadrature components.

1    19. (Original) The RFIC of claim 18, wherein the first multiplier module comprises:  
2         a first plurality of shift registers operably coupled to produce a plurality of shifted representations  
3         of the baseband in-phase components;  
4         switch matrix operably coupled to pass selected ones of the plurality of shifted representations of  
5         the baseband in-phase components and the baseband in-phase components based on the first coefficient;  
6         and  
7         an adder operably coupled to add the selected ones of the plurality of shifted representations of  
8         the baseband in-phase components and the baseband in-phase components to produce the normalized in-  
9         phase components.

1    20. (Original) The RFIC of claim 18, wherein the second multiplier module comprises:  
2         a first plurality of shift registers operably coupled to produce a plurality of shifted representations  
3         of the baseband in-phase components;  
4         switch matrix operably coupled to pass selected ones of the plurality of shifted representations of  
5         the baseband in-phase components based on the second coefficient; and  
6         an adder operably coupled to add the selected ones of the plurality of shifted representations of  
7         the baseband in-phase components to produce the cross coupled in-phase components.

1    21. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module comprises:  
2         a first multiplier module operably coupled to multiply the baseband in-phase components with the  
3         second coefficient to produce cross coupled in-phase components;  
4         a subtraction module operably coupled to subtract the cross coupled in-phase components from  
5         the baseband quadrature components to produce phase adjusted quadrature components; and  
6         a second multiplier module operably coupled to multiply the phase adjusted quadrature  
7         components with the first coefficient to produce the normalized quadrature components, wherein the  
8         baseband in-phase components are passed as the normalized in-phase components.

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1    22. (Currently Amended) The RFIC of claim 17, wherein the orthogonal-normalizing module  
2    comprises:

3                 a first programmable register for storing the first coefficient; and

4                 a second programmable register for storing the second coefficient, wherein the first and second  
5    coefficients are determined by a ~~trial-and-error~~ trial and error manufacturing test of the gain imbalance  
6    and the phase imbalance.

1    23. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module comprises:  
2                 a full matrix multiply module operably coupled to multiply the baseband in-phase components  
3    and the baseband quadrature components with a coefficient matrix that includes the first and second  
4    coefficients to produce the normalized in-phase components and the normalized quadrature components.

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1    24. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module further functions  
2    to:

3              measure local oscillation leakage power to produce a first power measurement;

4              provide a first magnitude signal to an in-phase portion of the transmitter section and a zero  
5    magnitude signal to a quadrature portion of the transmitter section;

6              measure power of the in-phase portion and power of the quadrature portion while processing the  
7    first magnitude signal and the zero magnitude signal, respectively, to produce a second power  
8    measurement;

9              provide the first magnitude signal to the quadrature portion of the transmitter section and the zero  
10   magnitude signal to the in-phase portion of the transmitter section;

11             measure the power of the in-phase portion and the power of the quadrature portion while  
12   processing the zero magnitude signal and the first magnitude signal, respectively, to produce a third  
13   power measurement;

14             determine the gain imbalance based on the first, second, and third power measurements;

15             provide a second magnitude signal to the in-phase portion and to the quadrature portion;

16             measure the power of the in-phase and quadrature portions while processing the second  
17   magnitude signal to produce a fourth power measurement;

18             provide the second magnitude signal to the in-phase portion and a negative second magnitude  
19   signal to the quadrature portion;

20             measure the power of the in-phase portion and the power of the quadrature portion while  
21   processing the second magnitude signal and the negative second magnitude signal, respectively, to  
22   produce a fifth power measurement; and

23             determine the phase imbalance based on the first, fourth, and fifth power measurements.

1    25. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module normalizes the  
2    orthogonal relationship between the baseband in-phase components and the baseband quadrature  
3    components by:

4              selecting one of the baseband in-phase components and the baseband quadrature components as a  
5    reference component; and

6              normalizing another one of the baseband in-phase components and the baseband quadrature  
7    components to the reference component.

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1 26. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module further functions  
2 to:

3 update the first and second coefficients to compensate for at least one of temperature variation  
4 and aging.

1 27. (Original) A method for orthogonal normalization of a radio frequency integrated circuit (RFIC),  
2 the method comprises:

3 determining phase imbalance and gain imbalance of a transmitter section of the RFIC;  
4 normalizing baseband in-phase components and baseband quadrature components of the  
5 transmitter section based on the phase imbalance and the gain imbalance of the transmitter section;  
6 coupling the transmitter section to a receiver section of the RFIC in a loop back configuration;  
7 providing a test signal from the transmitter section to the receiver section;  
8 determining power of baseband in-phase components, power of baseband quadrature components,  
9 and cross-correlation between the baseband in-phase components and the baseband quadrature  
10 components of the receiver section while processing the test signal; and  
11 normalizing the baseband in-phase components and the baseband quadrature components of the  
12 receiver section based on the power of the baseband in-phase components, the power of the baseband  
13 quadrature components, and the cross-correlation between the baseband in-phase components and the  
14 baseband quadrature components.

1 28. (Original) The method of claim 27, wherein the normalizing the baseband in-phase components  
2 of the receiver section comprises:

3 multiplying the baseband in-phase components with the first coefficient to produce the  
4 normalized in-phase components;  
5 multiplying the baseband in-phase components with the second coefficient to produce the cross-  
6 correlation; and  
7 subtracting the cross-correlation from the baseband quadrature components to produce the  
8 normalized quadrature components.

1 29. (Original) The method of claim 27, wherein the determining phase imbalance and gain imbalance  
2 of a transmitter section comprises:  
3       measuring local oscillation leakage power to produce a first power measurement;  
4       providing a first magnitude signal to an in-phase portion of the transmitter section and a zero  
5 magnitude signal to a quadrature portion of the transmitter section;  
6       measuring power of the in-phase portion and power of the quadrature portion while processing  
7 the first magnitude signal and the zero magnitude signal, respectively, to produce a second power  
8 measurement;  
9       providing the first magnitude signal to the quadrature portion of the transmitter section and the  
10 zero magnitude signal to the in-phase portion of the transmitter section;  
11       measuring the power of the in-phase portion and the power of the quadrature portion while  
12 processing the zero magnitude signal and the first magnitude signal, respectively, to produce a third  
13 power measurement;  
14       determining the gain imbalance based on the first, second, and third power measurements;  
15       providing a second magnitude signal to the in-phase portion and to the quadrature portion;  
16       measuring the power of the in-phase and quadrature portions while processing the second  
17 magnitude signal to produce a fourth power measurement;  
18       providing the second magnitude signal to the in-phase portion and a negative second magnitude  
19 signal to the quadrature portion;  
20       measuring the power of the in-phase portion and the power of the quadrature portion while  
21 processing the second magnitude signal and the negative second magnitude signal, respectively, to  
22 produce a fifth power measurement; and  
23       determining the phase imbalance based on the first, fourth, and fifth power measurements.

1 30. (Original) The method of claim 27, wherein the determining the power of baseband in-phase  
2 components, the power of baseband quadrature components, and the cross-correlation comprises:  
3       measuring in-phase signal level of the receiver section while processing the test signal; measuring  
4 quadrature signal level of the receiver section while processing the test signal;  
5       determining the power of the baseband in-phase components based on the in-phase signal level;  
6       determining the power of the baseband quadrature components based on the quadrature signal  
7 level; and  
8       determining cross-correlation power based on the in-phase signal level and the quadrature signal  
9 level.

1       31. (Original) The method of claim 27 further comprises:  
2             repeating the normalizing of the transmitter section and the receiver section to fine tune an  
3             orthogonal relationship between the baseband in-phase components and baseband quadrature components  
4             of the transmitter section and an orthogonal relationship between the baseband in-phase components and  
5             baseband quadrature components of the receiver section.

1       32. (Original) The method of claim 27 further comprises, in an ordered sequence:  
2             coupling the transmitter section to the receiver section in the loop back configuration;  
3             providing the test signal from the transmitter section to the receiver section;  
4             determining the power of baseband in-phase components, the power of baseband quadrature  
5             components, and the cross-correlation between the baseband in-phase components and the baseband  
6             quadrature components of the receiver section while processing the test signal;  
7             normalizing the baseband in-phase components and the baseband quadrature components of the  
8             receiver section based on the power of the baseband in-phase components, the power of the baseband  
9             quadrature components, and the cross-correlation between the baseband in-phase components and the  
10            baseband quadrature components;  
11            determining the phase imbalance and the gain imbalance of the transmitter section;  
12            normalizing baseband in-phase components and baseband quadrature components of the  
13            transmitter section based on the phase imbalance and the gain imbalance of the transmitter section; and  
14            repeating the ordered sequence of normalizing of the receiver section and the transmitter section  
15            to fine tune an orthogonal relationship between the baseband in-phase components and baseband  
16            quadrature components of the receiver section and an orthogonal relationship between the baseband in-  
17            phase components and baseband quadrature components of the transmitter section.